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PHYSICAL AND CHEMICAL PROPERTIES OF CALIFORNIA HONEYS

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PHYSICAL AND CHEMICAL PROPERTIES OF CALIFORNIA HONEYS[1]

J. E. ECKERT[2] AND H. W. ALLINGER[3]

INTRODUCTION

THE FIRST HONEYBEES were introduced into California in 1853, and since then the beekeeping industry in this state has grown to a position of first rank as compared to that in the other states.

The present bee population of California is estimated at between 300,000 and 345,000 colonies, which produce from 12 to 22 million pounds of honey annually. The colonies are located primarily in the irrigated regions, where the bees render invaluable services in the pollination of fruit, vegetable, and seed crops.

The length of the growing season in California and the wealth of the nectar and pollen plants in the cultivated and uncultivated regions of the state make it possible for beekeepers to practice a migratory system of beekeeping in order to keep the bees at work during the blooming periods of the many plants. This system of beekeeping tends to increase the production of surplus honey and to add greatly to the varieties of honeys that enter the commercial channels of trade. Migratory beekeeping also results in locating colonies in waste places and in often obscure mountain regions where they are rarely seen by the general public; and this tends to conceal the magnitude of the industry as a whole.

California has at least 175 species of plants of sufficient importance to be listed as yielders of pollen and nectar.[4] About 40 of these plants yield nectar in sufficient abundance during favorable seasons to produce commercial quantities of honey, but the great bulk of the honey in California comes primarily from a relatively small number of plants, such as the sages, alfalfa, citrus, cotton, yellow star thistle, California buckwheat, manzanita, and lima bean. While a majority of the important nectar-producing plants are uncultivated forms, made up mostly of native and introduced weeds, certain of the cultivated varieties also produce large quantities of honey and provide a very important source of pollen, which is essential to the well-being and development of the honeybee colony. Thus the deciduous fruit trees are valued by the beekeeper for the stimu-

[1] Received for publication October 24, 1938.

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[4] Vansell, G. H. Nectar and pollen plants of California. California Agr. Exp. Sta. Bul. 517:1–60. 1931. (Out of print.)

lating effect the nectar and pollen from their blossoms have on the growth of the colony, rather than for the small amount of strongly flavored surplus honey occasionally produced. This is also true for many of the truck crops and especially the cucurbits, although in rare instances commercial quantities of honey are produced from such plants as the onion and asparagus when they are grown for seed in sufficient quantities.

As a general rule, it is not practical to plant a given crop solely for the nectar or pollen produced, since bees have to range over too great an area to gather sufficient food for their own needs.[5]

The greater portion of the honey produced in California is in the extracted or liquid state, only a small quantity of the total being harvested in sections or in comb form. Honey to be extracted is stored by the bees in large combs, the cells of which are later uncapped by the beekeeper with a heated knife. The honey is extracted by centrifugal force in a special machine that does not injure the combs for further use. It is strained to remove particles of comb and allowed to remain in large tanks for several days until the air bubbles, incorporated in the extracting process, rise to the surface. The honey is then drawn into 5-gallon tin containers for the wholesale or bottling trades. Before honey is placed in retail containers, it is generally heated to retard granulation and to facilitate any further straining that may be necessary.

Despite the fact that honey is one of the oldest forms of sweet known to man, there is a general lack of knowledge concerning its chemical and physical properties. The present studies were undertaken to supply this technical information about the more important California honeys.

DEFINITION OF HONEY

The Service and Regulatory Announcements of the Food and Drug Administration, United States Department of Agriculture, gives the following definition of honey:

1. Honey is the nectar and saccharine exudations of plants gathered, modified, and stored in the comb by honeybees (*Apis mellifica* and *Apis dorsata*), is levorotatory, and contains not more than 25 per cent of water, not more than 0.25 per cent of ash, and not more than 8 per cent of sucrose.

2. Comb honey is honey contained in the cells of comb.

3. Extracted honey is honey which has been separated from the uncrushed comb by centrifugal force or gravity.

4. Strained honey is honey removed from the crushed comb by straining or other means.[6]

[5] Eckert, J. E. The flight range of the honeybee. Jour. Agr. Research 47(5):257–85. 1933.

[6] United States Department of Agriculture Food and Drug Administration. Definitions and standards for food products. U. S. Dept. Agr. Food and Drug Service and Regulatory Announc. F. D. 2:11. 5th rev. Nov., 1936.

The definition of honey in the Agricultural Code of California reads as follows:

"Honey" means the nectar of floral exudations of plants gathered and stored in the comb by bees (*Apis mellifica*). It is levorotatory, contains not more than twenty (20) per cent of water, not more than twenty-five one-hundredths [0.25] of one per cent of ash, not more than eight (8) per cent of sucrose, its specific gravity is not less than 1.412, its weight not less than eleven (11) pounds, twelve (12) ounces per standard gallon of 231 cubic inches at sixty-eight (68) degrees Fahrenheit.[7]

The chief discrepancies between these two definitions lie in the descriptions of the origin of honey and in the moisture content. The federal regulation is more inclusive in defining it as "the nectar and saccharine exudations of plants . . ." than the California code, which limits the source to "the nectar of floral exudations of plants. . . ." Certain honeys, such as cotton, are produced primarily from extrafloral nectaries and such would not be classified as true honeys under a strict interpretation of the words "floral exudations." The California Code places the maximum water content at 20 per cent, the federal definition at 25 per cent; furthermore, if the water content of honey is more than 20 per cent by weight, its specific gravity will be less than the requirement under the California regulations.

HOW HONEY IS PRODUCED

Although many are aware than honey is stored by the honeybee in combs from which it can be extracted by the beekeeper, there is still a difference of opinion as to how the nectar of flowers is converted by the honeybee into the finished product.

Only a limited number of references on the chemical composition of nectar are available, but the researches of Planta, Kenoyer, Caillas, Beutler, Park, Vansell,[8] and others, indicate that the nectar of different flowers is variable in the content of moisture, sugars, minerals, proteins, and other substances. The moisture and sugar content are the most variable factors in nectar; these differ not only with the plant but also with

[7] [California] Agricultural code. Sec. 840*k*. p. 192. 1937 revision. California State Department of Agriculture, Sacramento, California.

[8] Planta, A. von. Ueber die Zusammensetzung einiger Nektar-arten. Ztschr. Physiol. Chem. 10:227–47. 1886.

Kenoyer, Leslie Alva. Environmental influences on nectar secretion. Iowa Agr. Exp. Sta. Research Bul. 37:219–32. 1916.

Caillas, Alin. Composition and changes in nectar. Amer. Bee Jour. 66(5):226–27. 1926.

Beutler, Ruth. Sitzungsber. Gesell. für Morph. u. Physiol. in München 39. 1929. (Original not seen; reported in the Bee World 11(4):47–48. 1930.)

Park, Wallace. The storing and ripening of honey. Amer. Bee Jour. 64(7):330–32. 1924.

Vansell, G. H. The sugar concentration of some western nectars. Bees and Honey 18(5):150–51. 1937.

such environmental factors as temperature, moisture, light, soil, and atmospheric pressure. The total sugar content of nectar from various sources as given by Vansell is as follows:

Floral source	Total sugars, per cent	Floral source	Total sugars, per cent
Pear, Bartlett	9.0	Plum, variety unknown	32.0
Pear, Bartlett	10.2	Loco weed, *Astragalus Watsonii*	33.3
Pear, Bartlett	10.6	Manzanita	37.5
Cherry, sour	15.5	Peach, variety unknown	43.5
Peach, variety unknown	15.5	Cherry, Black Republican	50.8
Pear, Bartlett	16.9	Cherry, Royal Anne	60.8
Peach, variety unknown	17.2	Oregon grape	63.4
Cherry, mazzard	18.5	Maple, big-leaf	67.4
Flowering currant	18.9	Willow	70.7
Prune, Italian	21.7	Common mustard	71.2
Plum, Shiro	22.8	Maple, big-leaf	71.8
Pear, Duchess	23.8	Rape	72.6
Madrone	24.2	Red filaree	77.0
Prune, French or Petite	26.9		
Date-plum	30.5		

Nectar also contains certain enzymes, such as invertase, as is evidenced by the amount of reducing sugars present. Callais gives the following analysis for orange-blossom nectar:

Component	Per cent	Component	Per cent
Reducing sugars	17.640	Undetermined	0.628
Saccharose	8.217	Moisture	72.800
Dextrines	0.715		

The manner in which bees reduce the high percentage of moisture contained in nectar and invert the sucrose to dextrose and levulose has been the subject of investigation by many observers. For years the process was thought to be purely one of evaporation, that the bees add invertase to the nectar, deposit it in their combs, and then evaporate the excess moisture by causing air currents to be circulated through the hive by fanning their wings. Thomson[9] saw bees throw off a fine spray while flying between a point at which they were feeding on thin sirup and their hives, and concluded they were able to separate the excess water from nectar in their bodies while on wing. Various beekeepers of that same period, and before, had observed that field bees threw off a fine spray of a colorless liquid as they returned to their hives, which led to the rather general belief that bees could remove the excess moisture in nectar by physiological processes while flying. Doolittle[10] observed that the field bees on entering

[9] Thomson, C. How the bees remove the water from thin honey. Gleanings in Bee Culture 8(6):270–71. 1880.

[10] Doolittle, G. M. That new plan to prevent swarming. Gleanings in Bee Culture 22(6):462–63. 1894.

the hive gave their loads of nectar to house bees under 16 days of age and these in turn deposited the nectar in the cells.

Some years later Miller[11] observed that a bee whose honey stomach was filled with nectar would force out a small drop of liquid from her mouth and then withdraw it after a brief period, continuing the process for an undetermined length of time. He conjectured that this behavior was connected with the ripening or conversion of nectar into honey.

Brunnich[12] advanced another theory on the ripening of nectar that included the separation of a large part of the excess water from the nectar through the walls of the bee's honey stomach and thence to the exterior via the rectal glands and natural elimination while on wing.

Park[13] agreed with Doolittle and Miller but elaborated on the manner in which the bees handled the nectar to evaporate a large part of the moisture and to invert the sucrose into dextrose and levulose before placing it in the cells. Park[14] showed by later experiments that nectar could be ripened to the consistency of honey in about 3 days if the combs were placed behind a screen in a super of a hive. He further showed that nectar is not concentrated between the field and the hive by physiological processes within the bee. Numerous observations indicate that under normal conditions it takes about 3 days for the bees to convert nectar into ripe honey.

METHODS OF DETERMINATION AND ANALYSIS

Collection of Samples.—A collection of different samples of honeys produced in California was started for this study in 1932. In collecting the samples, an attempt was made to secure unheated honeys that were thought by the producer to be true to a given plant source. In some instances, however, an unknown amount of heat, generally insufficient to affect the color or flavor materially, had been applied during the process of extraction and clarification. A noticeable variation from the average for the source in color, flavor, or other properties in any of the samples probably indicates the presence of honeys from other plant sources rather than the change due to the application of heat. Since it is difficult for a producer to keep honeys from various sources wholly separate, the samples collected were considered to be typical of the general run of honeys to be found in the retail and wholesale trades.

[11] Miller, Arthur C. A mysterious act: peculiar habit of worker bees revealed by observation and its possible bearing upon current subjects of discussion. Amer. Beekeeper 14(1):7–8. 1904.

[12] Brunnich, K. About the bees' honey. Amer. Bee Jour. 59(2):56–57. 1919.

[13] Park, Wallace. The storing and ripening of honey. Amer. Bee Jour. 64(7): 330–32. 1924.

[14] Park, Wallace. How bees remove water from nectar. Iowa State Apiarist Rept. December 31, 1927. p. 83–88. 1927.

All samples were heated to 145° Fahrenheit and strained before the different determinations were made. When samples were received in the granulated condition, they were heated at 145° until all granules were dissolved. The honeys were then kept in airtight containers of glass or tin until needed. As the samples were secured over a period of five years, they were not observed on a comparative basis for granulating propensities.

Determination of Color.—The United States standard honey color grader, also known as the "Pfund color grader," was used to determine the colors of the honeys studied. This instrument is provided with a graduated scale to indicate the color equivalent and grade divisions. Thus honeys may be classified, according to color, into seven grades, as follows: Water white, 0 to 8; extra white, 9 to 16; white, 17 to 33; extra light amber, 34 to 48; light amber, 49 to 84; amber, 85 to 113; and dark, 114 to 140. The presence of green, red, or bright-yellow colors in some samples made close determination of the color grade difficult, because these colors are not compensated for in the amber-colored glass wedge of the color grader. Certain of the samples were rather turbid, even after they had been heated and strained. This turbidity is characteristic of some honeys and is not due entirely to small air bubbles held in suspension. Turbidity tends to give honey a darker appearance and a lower rating on the color grader than is the case when the same honeys are properly clarified. All color readings were made as soon as the samples were available.

Determinations of Weight and Moisture.—The weight per gallon and moisture content of each sample of honey were determined by the use of the Brix hydrometer and an Abbé refractometer according to methods and tables described by Marvin.[15] The moisture content was also determined chemically, as described later. Since the refractometer is coming into more common use for determining not only the weight per gallon and the moisture content of honey but also the percentage of sugar as indicated by the total solids, these equivalents are included in the tables with the chemical analyses.

Chemical Analyses.—The methods used in making the chemical analyses conformed throughout with the recommendations of the Association of Official Agricultural Chemists[16] with the exception of the acid deter-

[15] Marvin, G. H. Methods of determining the weight per gallon of honey. Amer. Bee Jour. 73:(11):426–28. 1933.

Marvin, G. H. The weight per gallon of honeys from various floral sources. Jour. Econ. Ent. 27(3):608–11. June, 1934.

[16] Skinner, W. W. Official and tentative methods of analysis of the Association of Official Agricultural Chemists. 4th ed. p. 487–89. Association of Official Agricultural Chemists, Washington, D. C.

minations, in which the acid was expressed in percentage of formic acid rather than in the number of cc of 0.1*N* NaOH per 100 grams of honey. This change was made in order to have the results comparable with those of other publications in which the acid content was expressed as formic. Furthermore, all polarization determinations were made with a 100-mm tube instead of a 200-mm tube.

The majority of the samples were more than one year old before it was possible to analyze them chemically.

Tabulation of Data.—In tables 1 and 2, the various honey samples are arranged alphabetically as to the floral sources indicated by the producers. The accuracy of such designations could not be positively checked by microscopical examinations of the included pollen grains. Where the chemical and physical determinations of a sample are at a considerable variance from the average for the same source, natural blending of nectar from more than one source during the extracting process should be suspected. Owing to unavoidable circumstances, the analyses could not be completed for honey samples nos. 39, 60, 87, 95, and 126.

SOME PHYSICAL CHARACTERISTICS OF HONEYS

Color.—The color grades of the different honeys as indicated by the scale on the Pfund grader ranged from 2 for a sample of black-sage honey to 131 for a sample of honey from eucalyptus. The scale of the Pfund grader is so constructed that a slight change in hue among the paler honeys often results in a different grade determination. A comparison of the grade points, therefore, is more indicative of the color variance than the color designation for each grade.

Color in honey depends on a combination of several factors. Tables 1 and 2 (p. 16) indicate considerable variation, in many cases, in the grade color of samples from the same floral source. One must take into account some of the causes of color in honey in order to explain or to understand these differences. Lothrop and Holmes[17] found that the color of honey increased with an increase in the colloidal constituents and that the clarity of honey was likewise affected. Most honeys contain small quantities of plant pigments, the value of which cannot be indicated accurately by the Pfund grader. Star-thistle honey, for example, has a very characteristic greenish cast not found in other California honeys. Alfalfa honey produced in valley districts of the state is uniformly darker in color than alfalfa honey produced at the higher elevations. The density of honey has little to do with color variations, but in retail pack-

[17] Lothrop, R. E., and R. L. Holmes. Determination of dextrose and levulose in honey by use of iodine-oxidation method. Indus. and Engin. Chem. analyt. ed. 3(3): 334–39. 1931.

TABLE 1

CHEMICAL AND PHYSICAL PROPERTIES OF THE MORE IMPORTANT CALIFORNIA HONEYS

Floral source and sample no.	Refractometric equivalents				Polarization constant at		Chemical analysis										L/D	Pfund reading	Color
	Refractive index	Moisture	Total solids	Weight per gallon	20° C	87° C	Moisture	Invert sugar	Sucrose	Dextrin	Total sugars	Ash	Acid	Undetermined	Levulose	Dextrose			
		pct.	*pct.*	*lbs.*			*pct.*	*pct.*	*pct.*	*pct.*	*pct.*	*pct.*	*pct.*	*pct.*	*pct.*	*pct.*		*mm*	
Alfalfa:																			
Valley:																			
No. 25	1.4990	14.9	83.5	11.96	− 9.7	+3.0	14.84	79.20	1.14	0.06	80.34	0.12	0.14	4.50	41.20	38.00	1.08	56	Lt. amber
No. 37	1.4950	16.5	82.0	11.87	− 8.8	+3.5	16.95	75.68	3.26	0.33	78.94	.23	.15	3.40	39.90	35.78	1.11	63	Lt. amber
No. 56	1.4933	17.3	81.3	11.84	− 9.4	+2.8	17.69	76.28	2.53	0.18	78.81	.10	.18	3.04	39.50	36.78	1.07	68	Lt. amber
No. 123	1.4970	15.8	82.7	11.92	− 9.2	+3.3	15.83	78.45	2.42	0.18	80.87	.19	.16	2.77	40.50	37.95	1.07	80	Lt. amber
High altitude:																			
No. 41	1.4973	15.7	82.8	11.92	− 7.4	+5.1	15.48	77.63	2.48	0.25	80.11	.15	.10	3.90	40.60	37.03	1.10	27	White
No. 42	1.4990	14.9	83.5	11.96	− 8.7	+4.0	14.97	78.34	1.74	0.17	80.08	.12	.11	4.55	41.20	37.14	1.11	20	White
No. 44	1.4989	15.1	83.4	11.96	− 9.2	+3.5	15.10	77.30	2.47	0.24	79.77	.08	.22	4.59	41.10	36.20	1.14	18	White
Processed:																			
No. 64	1.4984	15.4	83.1	11.94	− 8.5	+4.2	15.37	77.21	2.93	0.10	80.14	.18	.18	4.03	41.30	35.91	1.15	10	Ex. white
Average	1.4972	15.7	82.8	11.92	− 8.9	+3.7	15.78	77.51	2.37	0.19	79.88	.15	.15	3.85	40.66	36.85	1.10	43	.....
Apple:																			
No. 80	1.4900	18.5	80.1	11.77	− 8.3	+4.3	19.65	70.91	1.46	1.24	72.37	.32	.14	6.26	41.00	29.91	1.37	51	Lt. amber
Black locust:																			
No. 114	1.4905	18.3	80.3	11.78	−12.5	+0.2	18.26	74.00	2.91	0.29	76.91	.20	.18	4.16	40.90	33.10	1.24	57	Lt. amber
No. 116	1.4911	18.1	80.5	11.79	−12.5	+0.4	18.01	75.68	0.78	0.31	76.46	.22	.18	4.82	41.50	34.18	1.21	58	Lt. amber
Black locust and fruit bloom:																			
No. 35	1.4948	16.6	81.8	11.87	− 8.0	+4.5	16.48	76.19	1.89	0.89	78.08	.18	.17	4.20	40.60	35.59	1.14	79	Lt. amber
No. 74	1.4977	15.5	82.9	11.93	− 9.5	+3.2	16.00	78.18	1.80	0.13	79.98	.12	.13	3.64	41.20	36.98	1.11	42	Ex. lt. amber
Blue bell:																			
No. 33	1.4940	16.9	81.6	11.85	− 8.6	+4.0	16.02	78.34	1.10	0.54	79.44	.11	.13	3.76	40.90	37.44	1.09	59	Lt. amber
Blue curls:																			
No. 115	1.4925	17.6	81.0	11.82	− 1.0	+9.9	17.66	76.05	3.13	0.21	79.18	.12	.28	2.55	36.30	39.75	0.91	49	Lt. amber
No. 119	1.4917	17.9	80.7	11.80	− 1.3	+9.5	17.86	76.04	2.38	0.27	78.42	0.12	0.29	2.68	35.70	40.34	0.88	51	Lt. amber

Blue curls and cotton:																			
No. 28	1.4970	15.8	82.7	11.91	− 1.9	+8.7	15.40	75.33	3.22	0.76	78.55	0.19	0.22	4.88	35.10	40.23	0.87	33	White
California buckwheat:																			
No. 9	1.5005	14.4	84.1	11.99	− 7.5	+5.4	14.81	74.35	2.82	0.73	77.17	.14	.16	5.99	42.00	32.35	1.30	53	Lt. amber
No. 12	1.5008	14.2	84.2	12.00	− 8.9	+4.0	15.50	75.23	1.21	1.24	76.44	.14	.17	6.55	41.90	33.33	1.26	59	Lt. amber
No. 45	1.4941	16.9	81.7	11.85	−10.1	+2.9	16.02	76.19	1.87	1.01	78.06	.15	.17	4.59	42.10	34.09	1.23	55	Lt. amber
90 per cent buckwheat:																			
No. 104	1.4941	16.9	81.7	11.85	− 8.4	+4.0	16.80	76.40	0.85	0.47	77.25	.15	.14	5.19	40.30	36.10	1.12	55	Lt. amber
Average	1.4974	15.6	82.9	11.92	− 8.7	+4.1	15.78	75.54	1.69	0.86	77.23	.14	.16	5.58	41.58	33.97	1.22	55	Lt. amber
California buckeye:																			
No. 87	.....	....	....	11.77	.....	.....	18.53	71.53	1.07	1.04	.....	.42	.24	7.12	.....	.....	....	..	.....
Clovers:																			
Jack:																			
No. 29	1.4986	15.2	83.3	11.95	− 6.8	+5.7	15.27	76.54	2.38	1.61	78.92	.16	.18	4.06	40.70	35.84	1.14	49	Ex. lt. amber
White:																			
No. 68	1.4947	16.7	81.8	11.97	− 8.3	+4.5	16.61	77.50	1.12	0.13	78.62	.07	.08	4.49	41.60	35.90	1.16	15	Ex. white
No. 72	1.4990	14.9	83.5	11.96	− 7.6	+5.2	15.72	77.44	1.69	0.10	79.13	.08	.09	4.88	41.70	35.74	1.17	12	Ex. white
Ladino:																			
No. 112	1.4932	17.3	81.3	11.83	− 7.8	+4.6	17.30	75.66	1.56	0.21	77.22	.20	.20	4.87	40.40	35.26	1.14	48	Ex. lt. amber
No. 113	1.4932	17.3	81.3	11.83	− 7.7	+4.6	17.38	75.50	1.71	0.26	77.21	.16	.20	4.81	40.10	35.40	1.13	42	Ex. lt. amber
Sweet, and alfalfa:																			
No. 122	1.5016	14.0	84.5	12.01	− 8.2	+4.2	13.95	79.95	2.14	0.13	82.09	.10	.15	3.58	40.30	39.65	1.02	43	Ex. lt. amber
Average	1.4967	15.9	82.6	11.93	− 7.7	+4.8	16.04	77.10	1.77	0.41	78.87	.13	.15	4.45	40.80	36.33	1.13	35	.....
Cotton:																			
No. 24	1.4968	15.9	82.6	11.91	− 9.5	+3.5	15.29	79.40	0.37	0.71	79.77	.44	.20	3.59	42.10	37.30	1.13	28	White
No. 57	1.4963	16.0	82.4	11.90	− 9.8	+3.0	15.23	79.40	1.85	0.45	81.25	.54	.18	2.30	41.50	37.90	1.10	39	Ex. lt. amber
Coffee berry:																			
No. 77	1.4943	16.8	81.7	11.86	− 6.0	+6.3	17.81	72.24	1.14	1.61	73.38	.48	.18	6.54	40.20	32.04	1.26	86	Amber
Cherry, wild:																			
No. 84	1.4940	16.9	81.6	11.85	− 3.0	+8.7	17.27	75.30	2.56	0.19	77.86	.30	.09	4.29	39.10	36.20	1.08	66	Lt. amber
Eucalyptus:																			
No. 49	1.4891	18.9	79.8	11.75	− 9.4	+3.1	18.92	74.46	1.18	0.94	75.64	.22	.19	4.09	40.50	33.96	1.19	66	Lt. amber
No. 58	1.4900	18.5	80.1	11.77	− 9.8	+2.9	18.15	76.30	0.57	0.25	76.87	.22	.12	4.39	41.20	35.10	1.17	83	Lt. amber
90 per cent eucalyptus:																			
No. 109	1.4922	17.7	80.9	11.81	− 7.8	+4.6	17.65	74.00	2.56	0.99	76.56	.90	.21	3.69	40.40	33.60	1.20	131	Dark
Average	1.4904	18.4	80.3	11.78	− 9.0	+3.5	18.24	74.92	1.44	0.73	76.36	0.45	0.17	4.06	40.70	34.22	1.19	93	Dark

(Table concluded on next page)

TABLE 1—(*Continued*)

Floral source and sample no.	Refractometric equivalents				Polarization constant at		Chemical analysis										L/D	Pfund reading	Color
	Refractive index	Moisture	Total solids	Weight per gallon	20° C	87° C	Moisture	Invert sugar	Sucrose	Dextrin	Total sugars	Ash	Acid	Undetermined	Levulose	Dextrose			
		pct.	*pct.*	*lbs.*			*pct.*	*pct.*	*pct.*	*pct.*	*pct.*	*pct.*	*pct.*	*pct.*	*pct.*	*pct.*		*mm*	
Fleabane:																			
No. 76	1.4992	14.9	83.6	11.96	+13.5	+23.5	16.12	60.52	4.30	11.91	64.82	1.14	0.21	5.80	34.50	26.02	1.33	107	Amber
Goldenrod:																			
No. 79	1.4950	16.5	81.9	11.87	− 2.2	+ 9.7	17.40	73.41	1.37	1.12	74.78	0.37	.18	6.15	39.20	34.21	1.15	77	Lt. amber
Hyssop, western:																			
No. 83	1.4977	15.5	82.9	11.93	+ 2.4	+14.4	16.58	64.58	5.72	8.97	70.30	.81	.18	2.76	40.00	24.58	1.63	79	Lt. amber
Lima bean:																			
No. 38	1.4961	16.1	82.4	11.96	− 7.2	+5.5	16.15	74.46	4.53	0.30	78.99	.16	.12	4.28	41.40	33.06	1.25	26	White
No. 54	1.4930	17.4	81.2	11.92	− 8.6	+4.1	16.72	75.48	2.65	0.26	78.13	.12	.19	4.58	41.20	34.28	1.20	24	White
No. 59	1.4950	16.5	82.0	11.87	−13.1	−0.3	16.86	77.72	2.09	0.09	79.81	.15	.13	3.16	41.20	36.52	1.13	35	Ex. lt. amber
No. 63	1.4985	15.2	83.3	11.95	− 5.8	+6.5	15.58	73.44	6.86	0.02	80.30	.15	.12	3.87	40.20	33.24	1.21	15	Ex. white
No. 95	1.4934	17.2	81.4	11.84	.....	.....	16.63	75.85	2.14	0.41	77.99	.12	.18	4.67	40.10	35.75	1.12	17	White
No. 110	1.4965	16.0	82.5	11.91	− 8.3	+4.0	16.00	76.40	3.61	0.26	80.01	.10	.13	3.50	40.00	36.40	1.10	26	White
No. 124	1.4975	15.6	82.8	11.93	− 8.8	+3.7	15.70	78.30	2.57	0.24	80.87	.10	.16	2.93	40.60	37.70	1.08	33	White
Average	1.4957	16.3	82.2	11.91	− 8.6	+3.9	16.23	75.95	3.49	0.23	79.44	.13	.15	3.85	40.67	35.28	1.15	25	White
Lippia:																			
No. 31	1.5000	14.5	83.8	11.98	− 6.9	+5.6	14.77	76.65	2.71	0.71	79.36	.06	.10	5.00	40.70	35.95	1.13	35	Ex. lt. amber
Manzanita:																			
No. 7	1.4950	16.5	81.9	11.87	− 9.2	+3.8	16.77	73.95	2.19	0.20	76.14	.08	.12	6.69	42.20	31.75	1.33	20	White
No. 17	1.4950	16.5	81.9	11.87	− 3.7	+8.6	16.25	73.13	3.88	2.02	77.01	.39	.14	4.19	40.30	32.83	1.23	72	Lt. amber
No. 51	1.4928	17.4	81.1	11.82	+ 1.7	+11.7	17.41	74.52	2.98	1.27	77.50	.19	.11	3.52	33.50	41.02	0.82	28	White
No. 75	1.4931	17.3	81.3	11.83	− 2.4	+9.2	17.78	74.70	1.62	0.76	76.32	.20	.12	4.82	38.30	36.40	1.05	60	Lt. amber
No. 78	1.4960	16.2	82.3	11.87	− 5.5	+6.8	16.62	72.64	2.95	1.60	75.59	.43	.13	5.58	40.20	32.44	1.24	51	Lt. amber
Average	1.4944	16.8	81.7	11.85	− 3.8	+8.0	16.97	73.79	2.72	1.17	76.51	.26	.12	4.96	38.90	34.88	1.12	46	Lt. amber
Mint:																			
No. 61	1.4934	17.2	81.4	11.84	−12.3	+0.7	17.22	72.30	2.90	1.51	75.20	.43	.11	5.53	41.80	30.50	1.37	45	Ex. lt. amber
No. 65	1.4923	17.7	80.9	11.81	−12.0	+0.6	17.89	74.76	0.72	0.45	75.48	0.30	0.15	5.73	40.60	34.16	1.19	125	Dark

Mountain misery:																			
No. 4	1.4868	19.9	78.7	11.70	− 4.4	+7.7	19.36	71.32	2.07	1.21	73.39	0.23	0.09	5.72	39.70	31.62	1.26	69	Lt. amber
No. 82	1.4915	18.0	80.6	11.80	− 7.0	+5.6	18.12	69.12	1.78	2.82	70.90	.41	.14	7.51	41.10	28.02	1.47	93	Amber
Orange:																			
No. 13	1.4970	15.8	82.7	11.91	−10.8	+2.3	16.00	75.23	1.83	0.19	77.06	.14	.13	6.48	42.40	32.83	1.21	26	White
No. 14	1.4945	16.7	81.7	11.86	− 9.8	+3.0	16.76	75.92	1.46	0.02	77.38	.06	.10	5.68	41.50	34.42	1.21	25	White
No. 36	1.4970	15.8	82.7	11.91	− 7.4	+5.5	16.29	74.97	4.16	1.48	79.13	.08	.13	2.90	42.00	32.97	1.27	30	White
No. 39†	1.4906	18.3	80.3	11.78	− 9.0	+3.8	18.56	74.50	2.69	0.06	77.19	.08	.11	4.45	41.90	38.10	1.09	9	Ex. white
Liquid†	.....	....	....	.....	−14.2	−0.4	20.00	72.25	1.88	0.00	74.13	.07	.11	5.69	44.40	37.85	1.17	..	.....
Granul.†	.....	....	....	.....	− 3.8	+8.0	17.12	76.76	2.51	0.11	79.27	.08	.10	3.21	38.50	38.26	1.01	..	.....
No. 53	1.4950	16.5	81.9	11.87	− 8.2	+4.5	16.39	75.92	2.39	0.24	78.31	.08	.12	4.86	41.00	34.92	1.18	29	White
No. 55	1.4935	17.2	81.4	11.84	− 3.5	+7.7	17.03	67.25	11.00	0.27	78.25	.10	.14	4.24	36.80	30.45	1.21	29	White
No. 97	1.4969	15.8	82.7	11.91	− 7.0	+5.5	15.85	75.68	3.99	0.05	79.67	.07	.10	4.36	40.80	34.88	1.17	11	Ex. white
No. 99	1.5016	13.9	84.5	12.01	− 5.8	+6.6	14.01	75.50	5.51	0.14	81.01	.07	.11	4.66	40.50	35.00	1.16	22	White
Average	1.4958	16.3	82.2	11.89	− 7.7	+4.9	16.36	74.37	4.13	0.31	78.50	.08	.12	4.70	40.86	34.23	1.20	23	White
Rabbit brush:																			
No. 10	1.4964	16.0	82.5	11.90	−14.7	−1.7	15.13	75.83	0.56	3.22	76.39	.90	.45	3.91	41.60	34.23	1.22	77	Lt. amber
Rosin weed:																			
No. 32	1.4950	16.5	81.9	11.87	− 8.2	+4.0	16.10	77.98	1.98	0.83	79.96	.15	.20	2.76	39.60	38.38	1.03	68	Lt. amber
Sages:																			
Black:																			
No. 1	1.4972	15.7	82.8	11.92	−10.2	+3.3	16.05	74.00	2.55	0.59	76.55	.05	.10	6.66	43.70	30.30	1.45	4	Water white
No. 6	1.4949	16.6	81.8	11.87	−10.7	+2.7	16.65	75.62	1.41	0.28	77.03	.11	.10	5.83	43.40	32.22	1.35	8	Water white
No. 16	1.4970	15.8	82.7	11.91	− 9.1	+3.9	15.94	72.73	4.63	0.37	77.36	.06	.09	6.18	42.20	30.53	1.38	2	Water white
No. 101	1.4963	16.0	82.5	11.90	− 9.4	+3.2	16.00	75.68	3.08	0.11	78.76	.09	.10	4.94	40.80	34.88	1.17	3	Water white
Creeping:																			
No. 43	1.4995	14.7	83.6	11.97	−14.7	−1.0	14.79	76.30	2.42	0.85	78.72	.21	.15	5.28	44.00	32.30	1.36	31	White
No. 81	1.4950	16.5	81.9	11.87	−10.7	+2.8	16.98	71.70	1.63	2.50	73.33	.25	.15	6.73	43.70	28.00	1.56	51	Lt. amber
Purple:																			
No. 11	1.4961	16.1	82.3	11.90	−10.0	+3.5	16.36	74.72	1.46	0.84	76.18	.08	.09	6.45	43.80	30.92	1.42	6	Water white
White:																			
No. 103	1.4941	16.9	81.6	11.85	− 9.0	+3.7	16.85	76.28	2.33	0.21	78.61	.07	.07	4.19	41.20	35.08	1.18	14	Ex. white
Average	1.4963	16.0	82.4	11.90	−10.5	+2.7	16.20	74.63	2.44	0.72	77.06	.11	.11	5.78	42.85	31.77	1.35	15	Ex. white
Spikeweed:																			
No. 5	1 4910	18.2	80.4	11.79	− 5.2	+7.1	18.07	72.92	1.79	0.58	74.71	.25	.18	6.21	40.20	32.72	1.23	71	Lt. amber
No. 117	1.4965	15.9	82.5	11.91	− 9.5	+3.1	16.01	76.72	0.70	1.08	77.42	.30	.29	4.90	40.90	35.82	1.14	89	Amber
No. 120	1.4965	15.9	82.5	11.91	− 9.3	+3.1	16.05	76.52	1.10	0.69	77.62	.28	.27	5.09	40.20	36.32	1.11	88	Amber
Average	1.4947	16.7	81.8	11.87	− 8.0	+4.4	16.71	75.38	1.20	0.78	76.58	0.28	0.25	5.40	40.43	34.95	1.16	83	Lt. Amber

† Sample 39 had one-third of the honey liquid and two-thirds granulated; both portions were fermenting. The analyses are given for the sample as a whole and for the liquid and granulated portions separately; data for the separate sections are not included in the averages.

(Table continued on next page)

TABLE 1—(*Concluded*)

Floral source and sample no.	Refractometric equivalents				Polarization constant at		Chemical analysis										L/D	Pfund reading	Color
	Refractive index	Moisture	Total solids	Weight per gallon	20° C	87° C	Moisture	Invert sugar	Sucrose	Dextrin	Total sugars	Ash	Acid	Undetermined	Levulose	Dextrose			
		pct.	*pct.*	*lbs.*			*pct.*	*pct.*	*pct.*	*pct.*	*pct.*	*pct.*	*pct.*	*pct.*	*pct.*	*pct.*		*mm*	
Star thistle:																			
No. 2	1.5021	13.8	84.6	12.03	− 2.8	+8.8	14.50	72.95	6.13	0.60	79.08	0.08	0.17	5.57	38.20	34.75	1.10	35	Ex. lt. amber
No. 3	1.4990	14.9	83.5	11.96	− 2.4	+9.7	15.00	72.28	6.00	0.18	78.28	.07	.17	6.30	39.80	32.48	1.22	36	Ex. lt. amber
No. 20	1.4931	17.4	81.3	11.83	− 4.0	+8.0	16.96	72.97	3.75	0.58	76.72	.12	.21	5.41	39.40	33.57	1.17	32	White
No. 22	1.4952	16.4	82.1	11.88	− 3.0	+8.8	16.78	72.88	2.51	2.11	75.39	.24	.14	5.34	38.80	34.08	1.14	66	Lt. amber
No. 27	1.4949	16.6	81.8	11.87	− 4.5	+7.5	16.28	73.08	3.76	1.09	76.84	.11	.21	5.47	39.40	33.68	1.17	32	White
No. 34	1.4994	14.8	83.6	11.97	− 4.6	+7.5	14.80	75.93	3.39	0.91	79.32	.10	.19	4.68	39.70	36.23	1.10	47	Ex. lt. amber
No. 62	1.4950	16.5	81.9	11.87	− 3.7	+8.0	16.72	74.75	2.90	0.55	77.65	.09	.15	4.84	38.50	36.25	1.06	32	White
No. 69	1.4960	16.2	82.3	11.90	− 4.9	+7.3	16.33	75.02	3.99	0.56	79.01	.08	.14	3.88	40.00	35.02	1.14	44	Ex. lt. amber
No. 70	1.4977	15.5	82.9	11.93	− 6.3	+6.2	15.65	74.50	4.67	1.18	79.17	.08	.14	3.78	40.80	33.70	1.21	26	White
No. 71	1.4984	15.3	83.3	11.95	− 6.6	+5.8	15.28	74.50	5.34	0.56	79.84	.09	.16	4.07	40.40	34.10	1.18	42	Ex. lt. amber
No. 73	1.4960	16.2	82.4	11.90	− 5.8	+6.2	16.55	73.97	4.44	0.14	78.41	.10	.17	4.63	39.20	34.77	1.13	27	White
Average	1.4970	15.8	82.7	11.92	− 4.4	+7.6	15.90	73.89	4.26	0.77	78.15	.10	.17	4.91	39.47	34.42	1.15	38	White
Sumac:																			
No. 96	1.4967	15.9	82.6	11.91	− 6.8	+5.5	15.85	76.06	1.51	0.45	77.57	.25	.17	5.71	40.10	35.96	1.11	34	Ex. lt. amber
No. 108	1.4967	15.9	82.6	11.85	− 6.6	+5.3	16.85	75.80	1.79	0.88	77.59	.15	.10	4.43	38.80	37.00	1.05	66	Lt. amber
Sumac and toyon:																			
No. 100	1.4977	15.5	82.9	11.93	− 6.6	+6.0	15.45	74.50	0.90	2.08	75.40	.30	.15	6.67	41.10	33.40	1.23	58	Lt. amber
Tamarix:																			
No. 47	1.4895	18.7	79.8	11.76	− 9.4	+3.2	18.81	74.34	1.65	1.00	75.99	.29	.20	3.71	40.70	33.64	1.21	65	Lt. amber
No. 50	1.4982	15.3	83.2	11.94	−11.1	+1.4	14.75	78.80	0.94	0.32	79.74	.15	.19	4.85	40.30	38.50	1.05	109	Amber
Tarweed:																			
No. 15	1.4957	16.3	82.2	11.98	− 7.7	+5.0	16.23	75.92	1.46	0.62	77.38	.27	.09	5.41	41.30	34.62	1.19	73	Lt. amber
No. 46	1.4870	19.8	78.8	11.70	− 7.7	+5.0	19.80	74.61	0.12	0.64	74.73	.17	.30	4.36	41.30	33.31	1.24	81	Lt. amber
No. 85	1.4895	18.7	79.8	11.76	− 0.5	+10.8	19.25	68.87	2.21	2.69	71.08	.53	.17	6.28	37.50	31.37	1.20	94	Amber
No. 105	1.4902	18.5	80.2	11.77	− 8.1	+4.0	18.55	74.70	1.08	0.50	75.78	.14	.18	4.85	39.40	35.30	1.15	66	Lt. amber
No. 106	1.4935	17.2	81.4	11.84	− 8.8	+3.6	16.80	76.45	1.00	0.38	77.45	.17	.14	5.06	40.20	36.25	1.11	68	Lt. amber
No. 121	1.4917	17.9	80.6	11.80	− 8.4	+3.8	17.94	74.50	2.07	1.01	76.57	.28	.30	3.90	39.60	34.90	1.13	129	Dark
Average	1.4913	18.1	80.5	11.81	− 6.9	+5.4	18.10	74.18	1.32	0.97	75.49	0.26	0.20	4.98	39.88	34.30	1.16	85	Amber

Mountain honey, mixed sources:																		
No. 21	1.4993	14.8	83.6	11.97	− 4.4	+8.4	14.94	73.95	2.19	2.53	76.14	0.29	0.15	5.95	42.00	31.95	1.31	64	Lt. amber
Sage and buckwheat:																		
No. 126	.....	....	....	11.92	− 7.6	+4.7	15.17	76.05	5.08	0.23	81.13	.08	.15	3.24	40.10	35.95	1.11	26	White
Star thistle blend:																		
No. 125	1.4956	16.3	82.2	11.89	− 5.5	+6.6	16.20	75.12	4.07	0.19	79.19	.12	.19	4.11	39.60	35.52	1.12	59	Lt. amber
Star thistle and alfalfa:																		
No. 40	1.4980	15.4	83.2	11.94	− 4.3	+8.0	15.45	74.11	4.38	0.73	78.49	.28	.19	4.86	40.40	33.71	1.20	61	Lt. amber
Star thistle and California buckeye:																		
No. 52	1.4978	15.5	83.0	11.93	−12.3	+0.4	15.93	73.76	2.03	3.31	75.79	.02	.33	3.62	40.80	32.96	1.24	89	Amber
Unknown:																		
No. 60	.....	....	....	11.78	−11.0	+1.6	18.37	78.05	0.00	0.12	78.05	.18	.15	3.13	40.60	37.45	1.08	47	Ex. lt. amber
No. 93	1.4998	14.6	83.7	11.97	− 2.2	+10.0	14.62	76.40	2.53	1.14	78.93	.26	.10	4.95	40.20	36.20	1.11	56	Lt. amber
Wild alfalfa and age:																		
No. 102	1.4967	15.9	82.6	11.91	− 8.2	+4.4	15.85	76.40	2.00	0.18	78.40	.08	.10	5.39	41.00	35.40	1.16	25	White
Grand average	**1.4964**	**16.39**	**82.10**	**11.88**	**− 7.2**	**+5.2**	**16.50**	**74.95**	**2.53**	**0.91**	**77.53**	**0.21**	**0.16**	**4.72**	**40.41**	**34.54**	**1.17**	**49**	**Ex. lt. amber**
Honeydew honeys‡																		
Cedar:‡																		
No. 111	1.4994	14.8	83.6	11.97	+ 6.4	+16.5	14.80	67.08	3.72	8.86	70.80	0.70	0.20	4.64	34.2	32.9	1.04	92	Amber
No. 19	1.4990	14.9	83.5	11.96	+ 1.0	+13.8	17.44	65.24	3.52	7.12	68.76	0.73	.32	5.63	39.5	25.3	1.56	111	Amber
No. 23	1.5022	13.7	84.6	12.02	+17.0	+27.0	13.85	59.45	4.18	14.41	63.63	1.11	.37	6.63	35.1	24.4	1.44	140	Dark
No. 66	1.4995	14.7	38.6	11.97	+ 5.3	+16.3	15.65	62.76	5.74	10.88	68.50	0.60	.10	4.17	37.0	25.8	1.43	76	Lt. amber
Oak:‡																		
No. 18	1.5012	14.1	84.3	12.00	− 2.2	+10.5	15.23	69.83	1.36	6.34	71.19	0.73	.31	6.20	41.9	27.9	1.50	119	Dark
Unknown‡																		
No. 118	1.4930	17.4	81.3	11.83	.....	.....	17.36	63.60	2.18	7.63	65.78	0.73	.32	8.18	....	....	....	140	Dark
Average, honeydew honeys	1.4990	14.9	83.5	11.96	+ 5.5	+16.8	15.72	64.66	3.45	9.21	68.11	0.77	0.27	5.91	37.5	27.2	1.39	113	Dark

‡ The entries under "floral source" for honeydew honeys indicate the plant on which the honeydew producing insects were found.

TABLE 2

SOME PHYSICAL PROPERTIES OF SPECIAL SAMPLES OF CALIFORNIA HONEYS

Floral sources	Sample no.	Refractive index	Total* solids	Moisture* content	Weight* per gallon	Pfund grade	Color	Premium awarded	Fair at which samples were collected
			per cent	*per cent*	*lbs.*	*mm*			
Alfalfa	128	1.4930	81.25	17.4	11.83	34	Ex. light amber	4	State
	129	1.4900	80.10	18.4	11.77	28	White	1	Los Angeles
	130	1.4905	80.25	18.4	11.78	30	White	2	Los Angeles
	131	1.4985	83.35	15.2	11.95	28	White	3	Los Angeles
	132	1.4910	80.50	18.2	11.78	46	Ex. light amber	4	Los Angeles
	Av.	1.4926	81.09	17.5	11.82	33			
Buckwheat	133	1.4980	83.15	15.4	11.94	47	Ex. light amber	2	Los Angeles
	133-A	1.4955	82.20	16.3	11.89	45	Ex. light amber	..	Los Angeles
	134	1.4985	83.35	15.2	11.95	58	Light amber	3	Los Angeles
	135	1.4990	83.75	14.9	11.96	47	Ex. light amber	1	State
	135-A	1.4970	82.70	15.8	11.92	49	Light amber	..	State
	136	1.4982	83.15	15.3	11.95	48	Ex. light amber	2	State
	136-A	1.4867	79.50	19.0	11.74	43	Ex. light amber	..	State
	Av.	1.4961	82.54	16.0	11.90	48			
Blackeye bean	137	1.4980	83.15	15.4	11.94	55	Light amber	1	San Mateo
Lima bean	138	1.4932	81.25	17.3	11.84	24	White	1	Los Angeles
	139	1.4910	80.50	18.2	11.78	22	White	2	Los Angeles
	140	1.4900	80.00	18.4	11.77	23	White	3	Los Angeles
	141	1.4905	80.25	18.4	11.78	25	White	4	Los Angeles
	142	1.4951	82.00	16.5	11.87	11	Extra white	1	State
	143	1.4950	82.00	16.5	11.87	14	Extra white	2	State
	Av.	1.4929	81.00	17.6	11.82	20			
Cotton	144	1.4965	82.50	16.0	11.90	34	Ex. light amber	1	Los Angeles
	145	1.4961	82.40	16.1	11.90	27	White	1	Los Angeles
	146	1.4947	81.80	16.7	11.86	34	Ex. light amber	2	Los Angeles
	146-A	1.4986	83.40	15.2	11.95	29	White	..	Los Angeles
	147	1.4965	82.50	16.0	11.90	28	White	3	Los Angeles
	Av.	1.4965	82.52	16.0	11.90	30			
Orange	148	1.4978	83.00	15.5	11.93	10	Extra white	1	State
	149	1.4965	82.50	16.0	11.90	9	Extra white	1	Los Angeles
	150	1.4946	81.80	16.7	11.86	9	Extra white	2	Los Angeles
	151	1.4931	81.35	17.4	11.83	13	Extra white	3	Los Angeles
	152	1.4940	81.50	16.9	11.85	37	Ex. light amber	4	Los Angeles
	Av.	1.4952	82.03	16.5	11.87	16			
Sage	153	1.4960	82.35	16.2	11.89	8	Extra white	1	Los Angeles
	154	1.4960	82.35	16.2	11.89	12	Extra white	2	Los Angeles
	155	1.4940	81.50	16.9	11.85	10	Extra white	1	State
	156	1.4965	82.50	16.0	11.90	13	Extra white	2	State
	Av.	1.4956	82.18	16.3	11.88	11			
Yellow star thistle	157	1.4950	82.00	16.5	11.87	29	White	1	State
	158	1.4993	83.65	14.8	11.97	26	White	2	State
	159	1.4900	80.15	18.5	11.77	33	Ex. light amber	..	.....
	Av.	1.4948	81.93	16.6	11.87	29			
Grand average	36	1.4948	81.93	16.6	11.87	29			

* As determined by refractive index equivalents.

ages the depth of honey through which light rays have to pass adds considerably to the amount and value of the light rays absorbed, so honey in a thin glass container will appear lighter than the same honey in a container of larger diameter.

As indicated in table 3, honey darkens slowly with age. Heat likewise causes a rapid change in its color if too much heat is applied. Paine and Lothrop[18] found this to be due in large measure to the presence of amino acids, which combine with the sugars to produce dark-colored compounds. Honeys that contained relatively large quantities of colloidal constituents darkened to a greater extent than honeys which contained smaller quantities of colloids. The removal of the colloids by ultrafiltration methods reduced the tendency of such honeys to discolor or to caramelize when heated to the higher temperatures used in cooking. Lynn, Englis, and Milum,[19] on the other hand, found that darkening of honey is due primarily to instability of the fructose of honey.

Under commercial conditions of production, honey is often heated to 130° Fahrenheit to facilitate straining, and to between 145° and 160° for bottling. Honey will increase in color at these temperatures when allowed to cool slowly over an interval of several hours but little change will occur when the heat is applied quickly and cooling takes place rapidly: when honey that graded 30 on the Pfund grader was heated to 160° and poured into two 60-pound honey cans in a wooden shipping case, a temperature of 100° was recorded 24 hours later and a darkening of 10 grade points had taken place; but a series of California honeys of different sources and colors did not change appreciably in color when heated to 160° for 2 hours and then cooled within a few minutes.

Weight per Gallon.—The weight per gallon of honey is influenced by the moisture content, which, in turn, is affected by the floral origin, temperature, and humidity, as well as by methods used by the beekeeper in his manipulation of the combs during production. Honey that is extracted from the comb before the excess moisture has been completely evaporated by the bees is higher in moisture content and, therefore, weighs less per gallon than honey that has been thoroughly ripened by the bees before the combs are taken from the hive. This factor may easily nullify the effects of natural factors, so that only general deductions can be made in regard to the weights per gallon of the different honeys analyzed.

[18] Paine, H. S., and R. E. Lothrop. Influence of colloidal constituents on the development of color in honey. Amer. Bee Jour. 73(1):23, 27. 1933.
Paine, H. S., and R. E. Lothrop. Small plant for filtering honey. Gleanings in Bee Culture 63(7):395. 1935.

[19] Lynn, E. G., D. T. Englis, and V. G. Milum. Effect of processing and storage on composition and color of honey. Food Research 1(3):255–61. 1936.

TABLE 3

SOME PHYSICAL PROPERTIES OF HONEYS OF VARIOUS AGES
(Determinations made in 1938)

Floral source and sample no.	Age	Refractive index	Moisture	Solids	Weight per gallon	Pfund grade	Average color, fresh sample
	years		*per cent*	*per cent*	*pounds*	*mm*	
Alfalfa:							
No. 160	7	1.4973	15.7	82.8	11.92	75	Ex. lt. amber
No. 161	7	1.4969	15.8	82.6	11.91	125	Ex. lt. amber
No. 162	7	1.4962	16.1	82.5	11.90	126	Ex. lt. amber
No. 163	15	1.4977	19.5	83.0	11.72	140+	Ex. lt. amber
No. 164	14	1.5011	14.1	84.3	12.00	137	Ex. lt. amber
No. 165	14	1.4877	19.5	79.2	11.72	140+	Ex. lt. amber
No. 166	14	1.4992	14.9	83.6	11.96	127	Ex. lt. amber
Agastache, no. 167	7	1.4921	17.7	80.8	11.81	111	Ex. lt. amber
Cascara, no. 181	8	1.4930	17.4	81.2	11.83	140+	Amber
Cherry blossom, no. 168	15	1.4914	18.0	80.5	11.80	140+	Amber
Bean, lima:							
No. 169	12	1.4973	15.7	82.8	11.92	140+	White
No. 170	7	1.4979	15.4	83.0	11.94	106	White
No. 171	7	1.4965	16.0	82.5	11.90	118	White
Cotton, no. 172	12	1.5033	13.3	85.2	12.05	126	White
Carrot and asparagus, no. 173	9	1.4964	16.0	82.5	11.91	140+	Lt. amber
Holly, no. 174	8	1.4970	15.8	82.6	11.92	129	Lt. amber
Honeydew and incense cedar, no. 175	7	1.5077	11.8	86.7	12.10	140+	Amber
Buckeye and honeydew, no. 176	14	1.4875	19.6	79.0	11.71	140+	Amber
Buckeye, no. 177	7	1.4951	16.5	82.0	11.88	140+	Lt. amber
Buckeye and wild alfalfa, no. 178	7	1.4945	16.7	81.7	11.86	140+	Lt. amber
Mesquite, no. 179	15	1.5009	14.0	84.3	12.00	114	Lt. amber
Plum and mustard, no. 180	15	1.4925	17.6	81.0	11.82	140+	Amber
Orange:							
No. 182	14	1.5015	14.0	84.5	12.01	123	White
No. 183	11	1.4937	17.0	81.4	11.85	105	White
No. 184	9	1.4940	16.9	81.5	11.85	107	White
Sage and orange:							
No. 185	13	1.4961	16.1	82.4	11.90	118	White
No. 186	15	1.4981	15.4	83.2	11.94	121	White
Creeping sage, no. 187	7	1.4936	17.2	81.4	11.84	85	White
White and black sage, no. 188	14	1.4915	18.0	80.6	11.80	91	White
Sage:							
No. 189	9	1.5030	13.4	85.0	12.05	89	White
No. 190	16	1.4962	16.1	82.4	11.90	111	White
No. 191	7	1.4958	16.2	82.3	11.89	67	White
Star thistle and alfalfa, no. 192	15	1.4852	20.6	78.2	11.67	140+	Ex. lt. amber
Star thistle:							
No. 193	14	1.4943	16.8	81.6	11.86	140+	White
No. 194	14	1.5015	14.0	84.4	12.01	105	White
No. 195	15	1.5010	14.1	84.2	12.00	119	White
No. 196	14	1.4940	16.9	81.5	11.85	139	White
No. 197	15	1.4966	15.9	82.5	11.91	140+	White
No. 198	14	1.4990	14.9	83.5	11.96	131	White
Star thistle and alfalfa:							
No. 199	14	1.5077	13.5	84.9	12.04	140+	Ex. lt. amber
No. 200	15	1.5001	14.1	84.2	12.00	140+	Ex. lt. amber
No. 201	14	1.4910	18.1	80.5	11.79	140+	Ex. lt. amber
Star thistle and jagger weed, no. 202	15	1.5027	13.5	84.8	12.04	140+	Lt. amber

TABLE 3—(*Continued*)

Floral source and sample no.	Age	Refractive index	Moisture	Solids	Weight per gallon	Pfund grade	Average color, fresh sample
	years		*per cent*	*per cent*	*pounds*	*mm*	
Spikeweed:							
No. 203	8	1.4930	17.4	81.2	11.83	140+	Lt. amber
No. 204	8	1.4907	18.3	80.4	11.78	140+	Lt. amber
Blend:							
No. 205	13	1.4920	17.8	80.7	11.81	140+	Lt. amber
No. 206	14	1.4966	15.9	82.6	11.91	122	Lt. amber
No. 207	14	1.4930	17.4	81.2	11.83	140+	Lt. amber
No. 208	14	1.4925	17.6	81.4	11.82	140+	Lt. amber
No. 209	14	1.4975	15.6	82.9	11.93	140+	Lt. amber
No. 210	15	1.4975	15.6	82.9	11.93	140+	Lt. amber
Honeydew, incense cedar, no. 211	7	1.5027	13.5	84.8	12.04	139	Amber
Orange, no. 212	7	1.4970	15.8	82.7	11.92	126	White
Wild clover, no. 213	7	1.4982	15.3	83.2	11.94	123	Ex. lt. amber
Yellow star thistle, no. 214	13	1.4950	16.5	82.0	11.87	140+	White
Alfalfa, no. 215	8	1.4946	16.7	81.7	11.87	139	Ex. lt. amber

Only two samples—mountain misery no. 4 and tarweed no. 46—fell below the minimum weight per gallon, 11.75 pounds, set by the California Code. The average weight for all of the samples was 11.88 pounds per gallon, as determined by the use of the Abbé refractometer and Marvin's tables.

Granulation.—The granulation of honey is a natural physical characteristic influenced by a number of natural and artificial factors. Honey is, essentially, a supersaturated solution of three sugars, levulose, dextrose, and sucrose, so that crystallization may be expected to be the general rule rather than the exception. Phillips[20] pointed out that in the granulation of honey only the dextrose crystallizes and the levulose and sucrose remain in solution as a liquid film around the dextrose crystals. Since the dextrose hydrate crystal contains one less molecule of water than dextrose in solution, the percentage of moisture in the liquid phase of granulated honey is greater than when all of the sugars are in solution. An increase of the levulose content, expressed as the levulose : dextrose $\left(\frac{L}{D}\right)$ ratio, tends to retard granulation. This character is noticed particularly in the sage honeys of California, which are noted for their nongranulating qualities. Honeys produced from the nectars of blue curls, rosin weed, and tarweed, have the $\frac{L}{D}$ ratios of 0.88 to 0.91, 1.03, and 1.17, respectively, and are known to granulate very rapidly. In this

[20] Phillips, E. F. Some physical peculiarities of honey. Gleanings in Bee Culture 57(9):570–72. 1929.

investigation, granulation took place earlier in those samples of honey whose levulose: dextrose ratio was lower than the average for the same source, which demonstrates a variation in this factor within even a given source. Furthermore, honeys in the extracted form granulate faster than when left sealed in the comb, which indicates that the inclusion of air bubbles during the extracting process hastens granulation.

Another characteristic of the crystallization of honeys is that the speed of granulation has a direct bearing on the size of the crystals formed. Those honeys which granulate quickly form smaller crystals and hence have finer texture than those which granulate slowly. Crystallization is generally uniform in the fast-granulating honeys, but irregular in many honeys that granulate slowly. Stirring tends to hasten granulation and to reduce the size of the granules formed. Crystallization may be induced by adding small crystals of a finely granulated honey to liquid honey and distributing them uniformly throughout by stirring. The presence of dust particles in the containers or the inclusion of air bubbles during the extracting process also increases the tendency of a honey to granulate. Dyce[21] found that a temperature of 57° F was the most favorable for speedy granulation of the average-density honey, with the heavy honeys requiring 1° or 2° above this average.

Several of the samples of honey described in table 3 granulated solidly in the lower portion but were liquid on top. Sample 39 in table 1 granulated similarly, the liquid portion being much thinner than the whole sample after the granulated portion had been liquefied by heating. Partial granulation of a sample of honey can be induced by blending honeys of different specific gravities without the application of sufficient heat and by not stirring sufficiently to cause a uniform solution throughout. The same phenomenon occurs when honeys of different specific gravities are extracted and placed in the same tank: the lighter honeys will rise to the top, and the heavier portions below tend to granulate first.

The application of heat to granulated honey dissolves the crystals and tends to retard granulation. The length of time and degree to which a honey has to be heated to prevent granulation or to reliquefy it when it has granulated, varies somewhat with its type or floral source. Most of the honeys that granulated could be liquefied with the application of 145° F for a period of from 1 to 4 hours; but other honeys, and particularly mesquite honey, had to be heated to a higher temperature and for a longer period. The older honeys listed in table 3 had to be heated for a longer period than did the more recently produced samples from the same floral sources.

[21] Dyce, E. J. Crystallization of honey. Jour. Econ. Ent. 24(3):597–602. 1931.

A high sugar concentration retards fermentation in honey. Granulated honey is more prone to ferment than the same honey in the liquid condition because of the higher moisture content in the liquid phase surrounding the dextrose crystals. Since honey is hygroscopic, the probability of fermentation can be reduced by storing honey in air-tight containers in a dry atmosphere. Wilson and Marvin[22] found that temperatures below 52° F not only retarded the growth of the sugar-tolerant yeasts which cause fermentation but also prevented change in color of the honey samples.

Flavor.—One of the most important components of honeys is flavor, a character that is impossible to measure or describe adequately because of the variation in the preferences of different individuals.

As a rule, the characteristic flavor of a honey is definite and typical of the source from which it is produced, although the aroma is not necessarily the same as that of the flower. Sometimes the flavor closely resembles the aroma of the flower from which the nectar is gathered, but not all flowers yielding nectar are aromatic, and not all aromatic blossoms produce nectar.

The exact nature of the substances causing flavor in honey is not fully understood. Nelson[23] obtained by distillation a small residue from orange honey that had the odor and certain chemical properties of methyl anthranilate.

Not all of the honeys listed in table 1 could be described as pleasant or agreeable to the taste, and on this basis most honeys can be divided into two classes—table honeys and baking varieties. This distinction is not entirely suitable, however, because all of the more delicately flavored table honeys may be used in cooking; the flavors can be imparted to food products that do not require too high a temperature in their preparation. Since the stronger flavors of honeys are generally reduced or driven off at the higher temperatures without reducing the other admirable qualities of honey in connection with baked goods, the more flavorful honeys can be used for such purposes. Honeys derived from the California buckeye, prune blossoms, rabbit brush, rosin weed, tarweed, and others of similar strong flavor should not be sold in the general retail market as table varieties.

The flavors of honeys are more pronounced when the honey is finely granulated than when liquid or coarsely granulated. Many who sample a smoothly crystallized honey for the first time are very agreeably sur-

[22] Wilson, H. F., and C. E. Marvin. The effect of temperature on the keeping qualities of honey. Jour. Econ. Ent. 24(3):589–97. 1931.

[23] Nelson, E. K. The flavor of orange honey. Indus. and Engin. Chem. 22(4):448. 1930.

prised at the greater flavor. There is a greater demand for honeys that have a creamy consistency on granulating than for honeys that produce coarse crystals.

The older honeys listed in table 3 had lost much of the characteristic flavor and practically all of the typical aroma of more recent samples of the same floral sources.

ANALYTICAL DATA

Moisture.—The percentage of moisture in the honey samples listed in table 1 averaged 16.50 when determined chemically and 16.39 when determined by the Abbé refractometer, a difference of but 0.11 per cent: for practical purposes, the refractometric method of determining this factor in honey is evidently both accurate and feasible.

The moisture content (by analysis) ranged from 19.80 per cent in a sample of tarweed honey, no. 46, to 13.95 per cent for a combination of sweet clover and alfalfa honey, no. 122 (table 1). As stated previously, the percentage of moisture in honeys from the same floral sources may vary considerably because of manipulative practices during production. All samples were under the maximum limits for moisture set by the regulations of the Agricultural Code of California and over 5 per cent lower than the federal maximum.

Total Sugars.—The average total sugar content in the samples analyzed was 77.53 per cent, invert sugars constituting 74.95 per cent and sucrose 2.53 per cent. The invert sugars were made up of 40.41 per cent of levulose and 34.54 per cent of dextrose, or a levulose : dextrose ratio of 1.17.

The honeys with the highest average content of levulose were the sages, with 42.85 per cent; sage honeys also had the highest levulose : dextrose ratio. It is this feature that makes these honeys practically nongranulating.[24]

The honeys with the highest average content of invert sugar were : the alfalfas with 77.51, the clovers with 77.10, the lima beans with 75.95, the California buckwheats with 75.54, the spikeweeds with 75.38, and the eucalyptuses with 74.92 per cent; several single honey samples had comparable percentages.

The total sugar content, as determined chemically, was 4.57 per cent lower on the average than the total solids indicated by the refractometer. While a major portion of the total solids in honey is composed of the sugars, this discrepancy of 4.57 per cent should be taken into considera-

[24] There is a sample of sage honey in the honey collection at the University of California, at Davis, produced by the late M. H. Mendleson in 1886. The sample is now wine-red in color and has coarse crystals to the depth of an inch in the rather narrow glass container.

tion when the refractometer is used to indicate the percentage of sugars present.

The average percentage of sucrose present in the samples, 2.53, was well within both the state and federal regulations. In only one sample, orange blossom no. 55, did the percentage of sucrose exceed the regulations. In this sample, the 11.0 per cent of sucrose was unusual, for the moisture content of 17.03 per cent would indicate that the honey was

TABLE 4

Compilations of Tabular Data Based on Color of Samples

Color of sample	Number of samples	Refractive index	Weight per gallon	Moisture	Invert sugars	Sucrose	Total sugars	Dextrin	Ash	Acid	*L/D*
			lbs.	*pct.*	*pct.*	*pct.*	*pct.*	*pct.*	*pct.*	*pct.*	
Water white	5	1.4963	11.90	16.20	74.55	2.62	77.17	0.44	0.08	0.09	1.35
Extra white	7	1.4960	11.91	16.36	76.00	3.08	79.08	0.09	.10	.10	1.16
White	24	1.4963	11.90	15.99	75.68	2.92	78.60	0.48	.13	.15	1.15
Extra light amber	15	1.4973	11.92	15.71	75.90	3.03	78.93	0.56	.17	.16	1.14
Light amber	37	1.4943	11.85	16.86	75.20	1.95	77.15	0.91	.18	.17	1.16
Amber	7	1.4949	11.87	16.84	73.72	1.41	75.13	1.79	.31	.22	1.21
Dark	3	1.4920	11.81	17.82	74.42	1.78	76.20	0.81	0.49	0.22	1.18

not "green," although some of the moisture may have been removed by evaporation after the honey had been extracted.

Ash.—The ash content in the 106 samples averaged 0.21 per cent and ranged from 0.02 per cent to 1.14 per cent. Of the total number of samples examined, 22.6 per cent were above the legal limit set by state and federal standards. In data published by Lothrop,[25] 38.7 per cent of the samples reported had an ash content above the legal limit of the Pure Food and Drug Act. Since the ash content in pure honeys is so variable, it would seem desirable to set up a definite tolerance for this factor in order to prevent unwarranted discrimination against those above the average range.

A summary of the tabular data based solely on color, as in table 4, indicates that the percentage of ash increased directly with the color. As the ash of honeys is composed of the mineral elements, the darker-colored honeys have a higher mineral content than honeys of lighter-colored varieties. This is in agreement with the determinations of Lothrop,[26] who also found that the minerals in honeys are decidedly alkaline in reaction. Since the acids of foods are largely burned up in the body during diges-

[25] Lothrop, R. E. Adulteration of honey. Gleanings in Bee Culture 64(7):397–9. 1936.

[26] Lothrop, R. E. The mineral constituents of honey. Amer. Bee Jour. 76(7):346–47.

tion and metabolism, the acid-alkaline balance of the body is dependent almost entirely on the mineral elements present. Hence, honey can be considered potentially alkaline as a food.

Dextrin.—The dextrin content of the honey samples averaged 0.91 per cent but varied widely within honeys from the same floral source. The percentage of dextrin in the samples ranged from 11.91 per cent for fleabane honey, sample no. 76, to 0.02 per cent for lima bean honey no. 63 and a similar quantity for orange-blossom honey no. 14 (table 1).

Table 4 indicates a general increase in the dextrin content with an increase in color except for the extra white and the dark samples, which were unusually low.

Dextrin is evidently transmitted to honey through the nectar or may be an inclusion from other substances: Phillips[27] has shown that bees cannot utilize dextrin as a food and cannot change its chemical composition.

Acid.—The acid in the honey samples averaged 0.16 per cent and ranged from 0.45 per cent to 0.07 per cent. Table 4 indicates a tendency for the acid content to increase directly with the color of honey.

While the acidity of honeys is generally expressed as formic acid, the acid present in greatest quantity is probably malic acid and not actually formic acid at all.

Enzymes.—During the ripening process, the cane sugar in nectar is largely inverted by the honeybee through the action of the enzyme invertase into levulose and dextrose. Nectar itself contains invertase, but additional amounts of this enzyme are produced by glands in the honeybee. Other enzymes, such as diastase, catalase, and inulase have also been found in honeys in small quantities. Vansell and Freeborn[28] found that diastase in honey was derived from included pollens and therefore was not a true component of honey itself.

Undetermined Materials.—The undetermined materials averaged 4.72 per cent and ranged from 2.30 per cent to 7.15 per cent. This amount was slightly higher than the 3.73 per cent reported by Browne.[29] These undetermined compounds were probably composed of wax particles and pollen grains, as well as volatile acids, aromatic bodies, albuminoids, and other substances of unknown character. In general, the undetermined percentages were higher in those honeys which had a high dextrin content.

[27] Phillips, E. F. The utilization of carbohydrates by honeybees. Jour. Agr. Research 35(5):385–428. 1927.

[28] Vansell, G. H., and S. B. Freeborn. Source of honey diastase. Gleanings in Bee Culture 57(8):518. 1929.

[29] Browne, C. A. Chemical analysis and composition of American honeys. U. S. Dept. Agr. Bur. Chem. Bul. 110:1–93. 1907.

HONEYDEW HONEYS

The term "honeydew" is often applied to the saccharine exudations of extrafloral nectaries and other plant pores as well as the sweet excretions produced by certain insects feeding on plant growth. The bees gather these exudations at times when floral nectar is not available and convert them into a food product just as with floral nectar. Honey made from

Fig. 1.—*Quercus lobata,* the valley oak, produces honeydew at certain seasons of the year. The arrow indicates the point at which the honeybee collects the excretion. The galls on the leaves do not produce honeydew.

extrafloral nectaries cannot be distinguished from honeys made solely from nectar of floral origin, but there is a striking difference between these honeys and the products made from the sweet excretions of certain insects. Consequently, the term "honeydew honey" should be applied only to the latter and not to such honeys as are made solely from nectar of plant origin.

In California many tons of honeydew honey are produced on a commercial basis from the sweet excretions of certain insects belonging to the Coccidae (scale insects), Aphidae (plant lice), Jassidae (leafhoppers), Membracidae (tree hoppers), and Cynipidae (gall insects). The formation of this sweet excretion is little understood, but it is produced in large quantities from various pines, cedars, firs, oaks, willows, etc. The

largest quantities are produced from the incense cedar (*Libocedrus decurrens*) and the valley oak (*Quercus lobata*) (fig. 1). Honeydew honey is especially plentiful in dry seasons, which are favorable to the insect development. The product is generally dark in color and undesirable in flavor, although some beekeepers report crops of honeydew which are light in color and of excellent flavor.

The six samples of honeydew honey analyzed (table 1, p. 10) differed considerably from the honey samples in both composition and physical properties. They were dextrorotatory, low in invert sugars, and high in dextrins and ash. They were extremely viscous, a character that readily distinguishes them from the floral varieties of honey. Despite their dark color, honeydew honeys have been found to have many highly desirable qualities when used in the bakery trade.

SUMMARY

Our studies have shown that honeybees in California produce a variety of honeys that differ in physical and chemical properties with the floral sources from which they are produced. Thirty-seven of these different types have been described and analyzed chemically, together with other samples of mixed origin. Specific samples are at times difficult to obtain because of the blending of honeys from different sources by the honeybee in the comb or during the extracting process.

Analysis of all samples indicated that the average California honey consisted of the following components, in percentages of the total: moisture, 16.50, total sugars, 77.53; levulose, 40.41; dextrose, 34.54; sucrose, 2.53; dextrin, 0.91; ash, 0.21; acid, 0.16; and undetermined, 4.72. The levulose : dextrose ratio was 1.17, the weight per gallon 11.88 pounds, and color 49, or extra light amber.

The use of the refractometer to determine the moisture and sugar content of honey as well as the weight per gallon, was found to be close enough to the chemical determinations to warrant this less expensive method in making determinations of these factors.

Various samples of honey have been shown to darken with time and temperature. Obviously, honey should not be heated to a temperature or for a length of time that will injure its color or flavor, and less change in the color of honey is to be expected if honey is stored at a cool temperature than at higher temperatures.

The samples of honey conformed to all standards of quality set by the state and federal regulations with the exception of the ash content. The fact that 22.6 per cent of the samples here reported are above the legal maximum ash content would indicate that a greater tolerance in the

official limits should be made in order to prevent discrimination against certain commercial honeys.

The honeydew honeys examined were shown to differ considerably in chemical and physical properties from the samples from floral sources and consequently should not be confused with the floral honeys. While honeydew honeys cannot be considered in the class with table honeys, they should be quite acceptable to the bakery trade.

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